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(56) Documents cited
GB 1552419
GB 1536675
GB 1481707
GB 1471916
GB 1420313
GB 1361485
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(54) Diesel engine with ultrasonic atomization of fuel injected

(57) The fuel injector 12 or a surface onto which the fuel is injected is ultrasonically vibrated to effect fuel atomization. The injector 12 may be located in a pre-combustion chamber 14 or engine cylinder. The injector may be connected to a high voltage source to electrostatically charge the fuel.

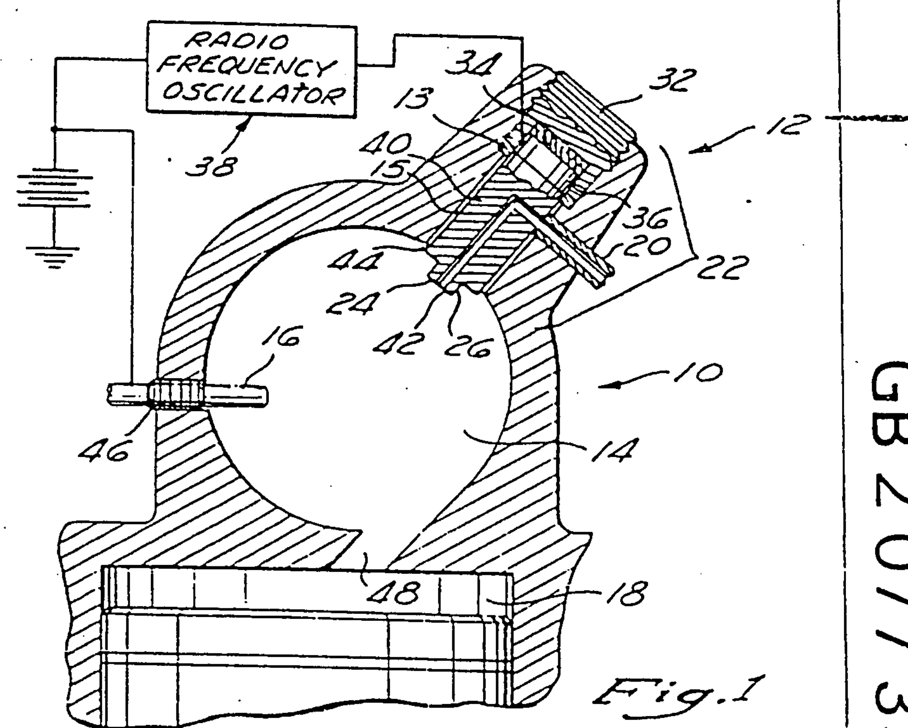

Fig. 1

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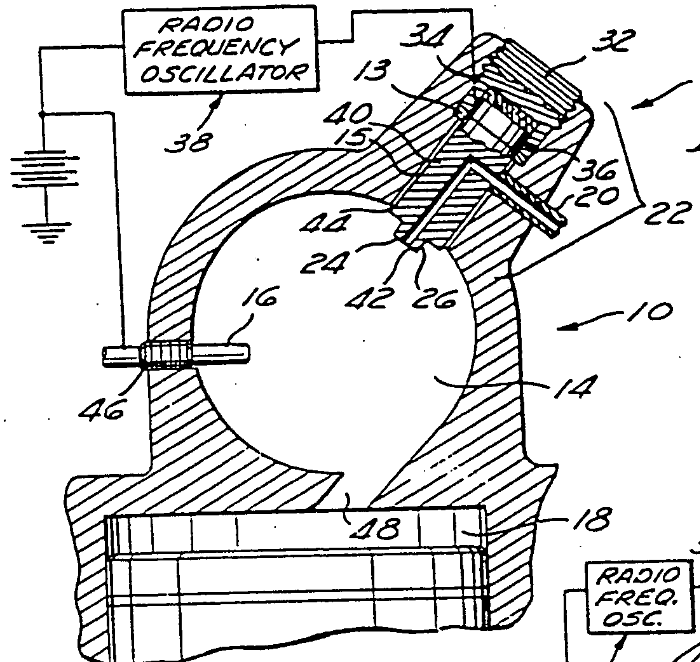

Fig.1

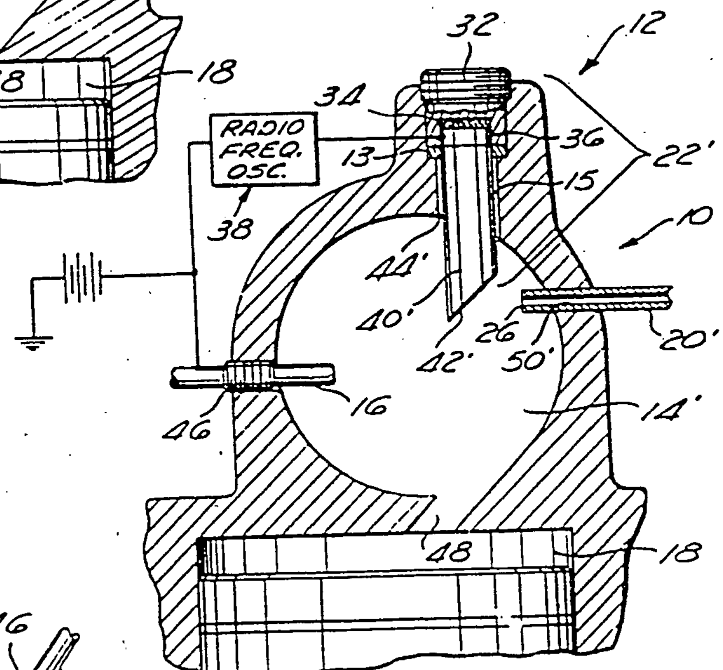

Fig.2

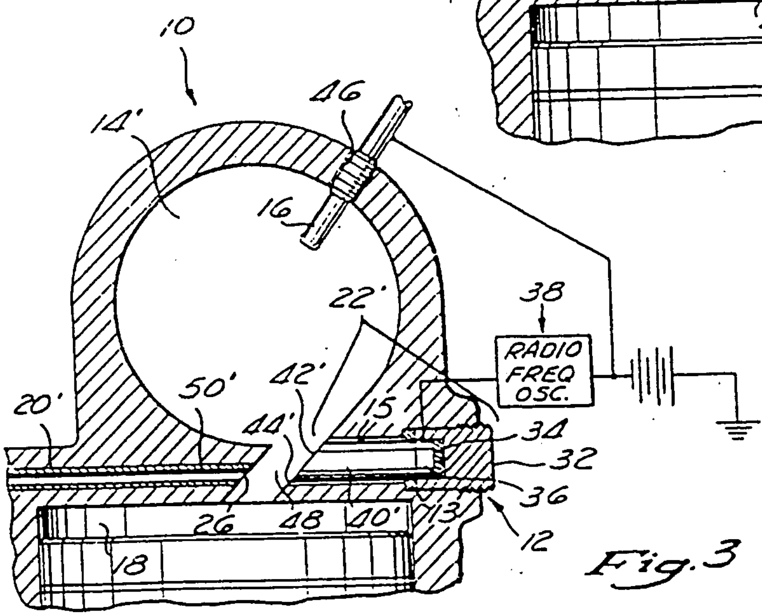

Fig.3

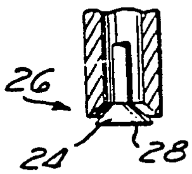

Fig. 4

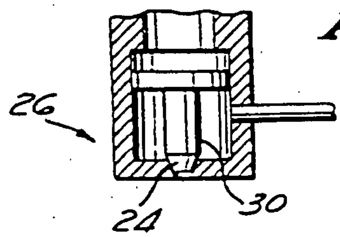

Fig. 5

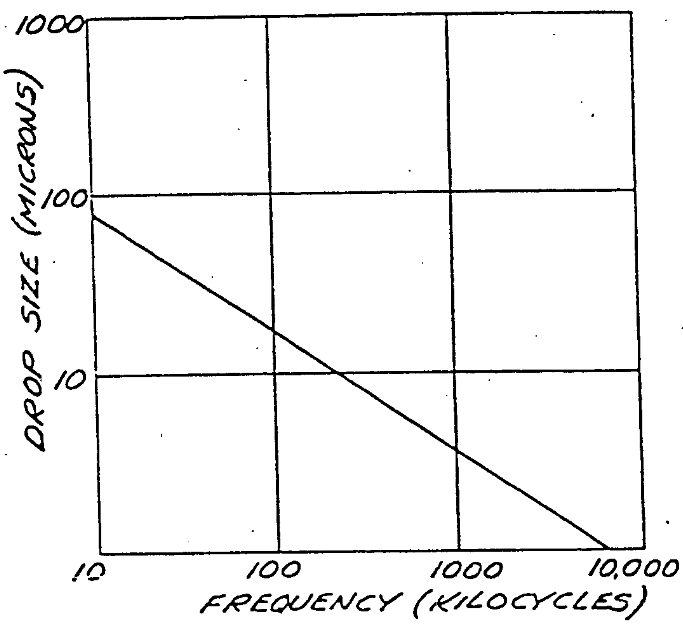

Fig. 6

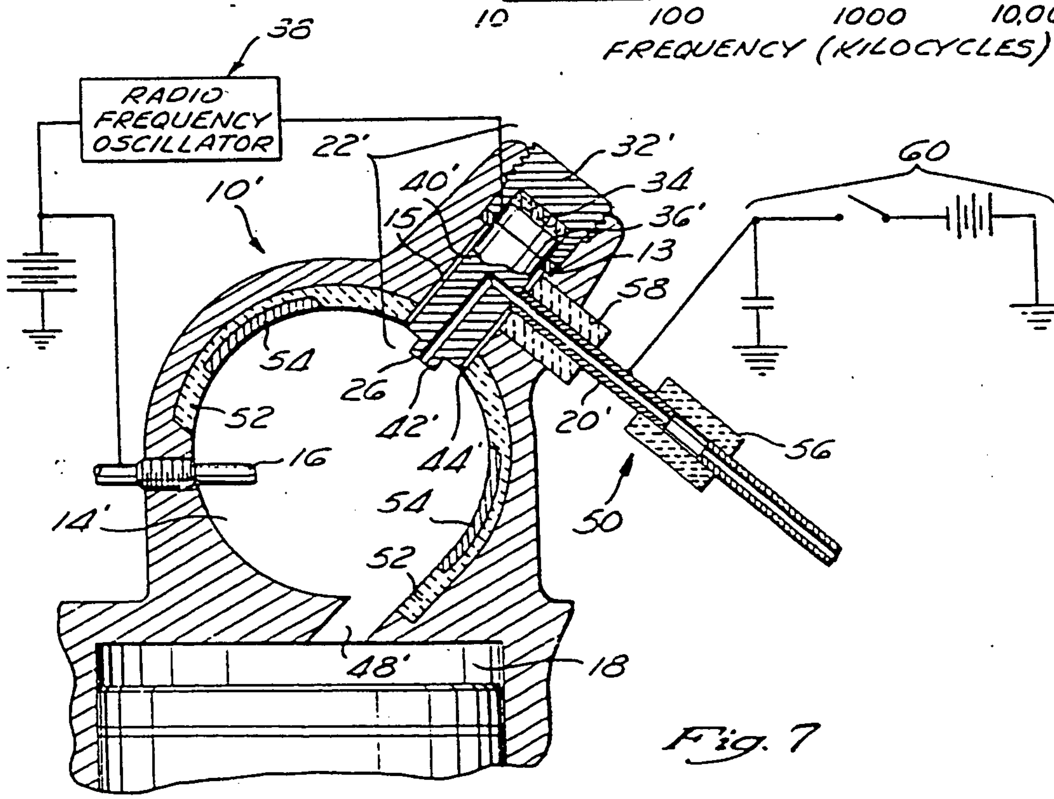

Fig. 7

SPECIFICATION
Diesel engine with improved fuel injector

Diesel engines designed according to the precombustion chamber system have the combustion chamber divided into a precombustion chamber, which is incorporated into the cylinder head, and a main combustion chamber which is positioned between the bottom edge of the cylinder head and the crown of the piston. The precombustion chamber into which the fuel is injected and in which combustion initially take place, is connected to the main combustion chamber by means of a narrow slot or flow passage.

In operation, as the piston moves in the direct of the cylinder head, air is forced into the precombustion chamber, and near the end of this compression stroke fuel is injected into the precombustion chamber. Subsequently, the combustion products are returned through the flow channel from the precombustion chamber into a secondary combustion chamber formed in the piston head. The combustion of this fuel-air combination generates the thrust necessary to produce the power stroke of the piston.

US Patent No 4,122,804 describes a diesel engine designed in accordance with precombustor theory and having a precombustion chamber using a pencil-type fuel injector.

It is an object of the present invention to provide for efficient atomization of fuel in a diesel engine combustor, with the consequent advantages of a highly efficient diesel engine which burns fuel more completely, so that the particulate matter output and production of nitrous oxides are significantly decreased.

According to the present invention there is provided a diesel engine comprising an ultrasonic fuel injector for atomizing fuel in a combustion chamber thereof.

Ultrasonic vibrations in the injector produce fine fuel droplet sizes. Combustion theory and basic combustion experiments indicate that reducing fuel droplet size will enhance combustion efficiency and decrease the tendency for diesel engine combustion to produce particulates. The very small particle sizes, of the order of 0.1 to 10 microns, required to effect this increase in combustion efficiency and reduction in pollutants, are produced by ultrasonically vibrating the fuel as it passes from the ultrasonic injector into the combustion chamber.

In the preferred embodiment, an AC current of about 1000 kHz is applied to a transducer causing it to expand and contract in a linear fashion. These ultrasonic vibrations are concentrated by a horn having an active surface capable of transmitting these ultrasonic vibrations to fuel which is flowed across the active surface. The rapid motion exerts a radiation pressure within the fuel film resulting in atomization of the fuel.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figs. 1 to 3 are schematic cross-sectional views of precombustion chambers and ultrasonic fuel injectors.

Fig. 4 is a schematic view of a poppet valve incorporated into the injector body.

Fig. 5 is a schematic view of a pintle valve incorporated into the injector body.

Fig. 6 is a graphical representation of fuel droplet size versus frequency.

Fig. 7 is a schematic cross-sectional view of a precombustion chamber having an ultrasonic/electrostatic fuel injector.

Turning now to Figs. 1—3, these are shown three embodiments of the precombustor 10, which comprises an ultrasonic injector 12, combustion chamber 14 and flow plug 16. It should be noted that although it is preferred to incorporate the ultrasonic fuel injector 12 through a seal 13 into the precombustion chamber 14, the ultrasonic injector 12 could similarly be incorporated into the engine cylinder 18.

The ultrasonic fuel injector 12 comprises a fuel inlet 20 and an ultrasonic element 22. Although the fuel inlet 20 can be merely a tubular element, as shown in Figs. 1—3, the preferred system would include a check valve 24 near the outlet 26 or a velocity node of the fuel inlet 20. As examples of check valves, Figs. 4 and 5 show a poppet valve 28 and a pintle valve 30 respectively.

The ultrasonic injector 12 comprises a base plug 32, an optional insulator 34 fixed on the inner face of the plug for attenuating back vibrations, and a transducer 36 for inducing high amplitude, high frequency oscillations. The transducer is connected either directly or through the optional insulator 34 to the inner face of the plug 32, and electrically connected to a AC voltage source 38. A concentrating horn or nozzle is fixed to the inner face of the transducer 36. The horn 40 can be of basically any geometric configuration, although a stepped horn, Fig. 1 is preferred; horns of various geometric shapes and sizes are described in Ultrasonic Engineer, Julian Roos Frederick, New York J. Wiley 1965, pages 52 to 57. The concentrating horn 40 has an active surface 42 for atomizing the fuel as it passes from fuel inlet 20, across the active surface 42 and into the combustion chamber 14

The transducer 36 can be a magnetostrictive element or a piezoelectric element. In operation, an AC current is applied to the transducer 36 causing it to expand and contract linearly in accordance with the frequency of the applied AC current, while the amplitude is controlled by current density and transducer design. Fig. 6 shows the dependence of droplet size on frequency in ultrasonic atomization.

Although any conventional precombustion chamber shape will work with this invention, the preferred precombustion chamber 14 shape is spherical. The precombustion chamber 14 shown in Fig. 1 includes an ultrasonic injector port 44 through which both the ultrasonic element 22 and the fuel inlet 20 are inserted. Igniter port 46 is located in an area opposed to the ultrasonic

injector port 44 and is sized to receive a means for igniting the fuel-air mixture such as the glow plug 16. Finally, flow passage 48 through which air is injected into the precombustion chamber 14 and through which combusting gases escape into engine cylinder 18 is located so as to transport atomized fuel and incoming air to the igniting means 16.

In the embodiments shown in Figs. 2 and 3, ultrasonic injector 12 is divided into two components, fuel inlet 20' and ultrasonic element 22', thereby requiring precombustion chamber 14' to have a fuel inlet port 50 and an ultrasonic element port 44'. The fuel impinges on the active surface 42' of the horn 40' on the transducer 36.

In operation, the very small droplets required to effect the efficient burning objective of the present invention are produced in the following manner: An AC current having a frequency of about 1000 kHz is applied to transducer 36 causing ultrasonic vibrations. These vibrations are concentrated by horn 40 which passes through seal 13 and clearance 15 into the diesel engine combustion chamber 14. Seal 13 should preferably be located at a velocity node of the horn so as to minimise the dissipation of the ultrasonic energy. The fuel is then flowed through fuel inlet 20 and on to active surface 42. The fuel flow is preferably directed so as to evenly distribute it across the active surface 42 of horn 40 where the rapid motion of the active surface 42 exerts a radiation pressure within the fuel film which is resting on the transducer tip, or in the colum of fuel that is being fed into the transducer on a continuous basis. This radiation pressure causes vibrations on the surface of the fuel in such a way that capillary waves are formed. The amplitude of strain within the fuel film which is in contact with the vibrating transducer is sufficient at certain times to exceed the surface tension and tensile strength of the fuel and a free droplet forms, approximately the size of the half-wavelength of the capillary waves. Since the droplets are very small and are launched from the active surface 42 in a dispersed manner and without much penetrating power, the ultrasonic injector 12 or 22' should be located where the motion of the inflowing air in the combustion chamber 14, 14' can entrain the droplets and cause them to be mixed with the combustion air. A preferred location for fuel inlet 20' and ultrasonic element 22' is in or near flow passage 48 as described in Fig. 3.

It should be noted that the ultrasonic injector 12 can further comprise an electrostatic charging means as shown in Fig. 7 and described in our copending British Patent Application No. 8040942 (Serial No.). In this embodiment, combustor 10' comprises combustion chamber 14' having an ultrasonic injector port 44' through which ultrasonic injector 12' is inserted, igniter port 46' for flow plug 16', and flow passage 48'. Ultrasonic fuel injector 12' further comprises an ultrasonic element 22' including backing plug 32', vibration attenuator 34', transducer 36', and horn 40' having active surface 42', and fuel injector 20' for flowing fuel onto active surface 42'. Electrostatic components may be added to the above ultrasonic components to enhance atomization. These components include electrostatic element 50 and electrical insulations 52 and electrodes 54 incorporated along the interior wall of chamber 14'. Electrostatic element 50 further comprises electroconductive injector body 20' which also serves as fuel injector 20', having at least one fuel inlet and at least one fuel outlet, means 56 and 58 for electrically insulating the injector body from the diesel engine, and means 60 for charging the injector body in a range from about 10,000 to about 100,000 volts.

CLAIMS

1. A diesel engine comprising an ultrasonic fuel injector for atomizing fuel in a combustion chamber thereof.

2. An engine according to claim 1, wherein the fuel injector comprises a nozzle and an ultrasonic transducer exciting vibrations in the nozzle.

3. An engine according to claim 1, wherein the fuel injector comprises an ultrasonic transducer exciting vibrations in an atomizing body, and a nozzle directed to cause fuel issuing therefrom to impinge on the atomizing body.

4. An engine according to claim 1, 2 or 3, wherein the injector is disposed in a precombustion chamber.

5. An engine according to claim 1, 2 or 3, wherein the injector is disposed in an engine cylinder.

6. An engine according to any of claims 1 to 5, further comprising means for applying a high voltage to the injector to provide electrostatic fuel injection.

7. An engine according to claim 1, wherein the ultrasonic fuel injector comprises an ultrasonic element including means for anchoring said ultrasonic fuel injector said engine; means for inducing high amplitude, high frequency oscillation axially connected to said anchoring means; means for concentrating said high amplitude, high frequency oscillations axially connected to said inducing means and wherein said concentrating means has an active surface; and means for flowing fuel onto said active surface of said means for concentrating said oscillation.

8. An engine according to claim 7, wherein said anchoring means comprises a backing plug.

9. An engine according to claim 8, wherein said ultrasonic element further comprises an insulator interposed between said anchoring means and said means for inducing high amplitude, high frequency oscillations, for attenuating back oscillations.

10. An engine according to claim 7, wherein said means for inducing high frequency oscillations, comprises a voltage source; and a transducer electrically connected to said voltage source and axially connected to said anchoring

means.

11. An engine according to claim 10, wherein said transducer is a magnetostrictive element.

12. An engine according to claim 10, wherein said transducer is a piezoelectric element.

13. An engine according to claim 7, wherein said means for concentrating said high amplitude, high frequency oscillations is a horn.

14. An engine according to claim 7, wherein said means for flowing fuel onto said active surface of said means for concentrating high amplitude, high frequency oscillations comprises a fuel injector nozzle.

15. An engine according to claim 14, wherein said fuel injector nozzle is axially oriented through the horn.

16. An engine according to claim 14, wherein the fuel injector nozzle is oriented so that it is opposed to said active surface.

17. An engine according to claim 14, wherein the fuel injector further comprises a check valve oriented within the fuel injector nozzle.

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